FRONTAL EEG ASYMMETRY TO PERCEIVED GAZE DIRECTION OF ANIMATE AND INANIMATE MODELS IN 5- AND 7-YEAR-OLD CHILDREN

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Eye gaze plays an important role in social interaction. Eye gaze direction provides a cue of what may be in the other person's mind. According to recent studies in adults, the perceived gaze direction of another person influences the observer's neural affective-motivational responses of approach and avoidance. The aim of this study was to examine whether seeing direct versus averted gaze influences affective-motivational neural responses in children and whether it would make a difference to these responses if children viewed the face of a human or a dummy. Two age groups (5- and 7-year-olds) were compared to examine the effect of age on these neural responses. Possible differences in the amount of animistic thinking exhibited between the age groups were expected to affect the neural responses.

It is a widely held view that approach-related motivation enhances relative left-sided frontal EEG activity, whereas avoidance-related motivation enhances relative right-sided frontal EEG activity. Based on earlier studies in adults, it was expected that the perceived direct gaze of a human would elicit left-sided frontal EEG asymmetry (indicative of approach-related motivation) and the perceived averted gaze of a human would elicit smaller left-sided frontal EEG asymmetry or right-sided frontal EEG asymmetry (indicative of avoidance-related motivation) in both 5- and 7-year-olds. Research suggests that especially young children may have difficulty distinguishing living entities from the non-living. Children may attribute human properties to inanimate agents, which is referred to as animistic thinking. In the present study, it was expected the 5-year-olds would likely exhibit animistic thinking regarding the dummy and that the perceived gaze direction of the human and the dummy would therefore elicit similar neural responses. Studies indicate that animistic thinking decreases during the preschool years, and it was expected that only the perceived gaze direction of the human would influence the neural approach-avoidance responses in the 7-year-olds. In the experiment, power in the alpha band from the left and right frontal channels (F4/F3 and F8/F7) was measured with EEG. Several alpha bands were tested in the analyses to ensure the capturing of the alpha band applicable to children (6–9 Hz, 6–12 Hz, 8–13 Hz). An animism questionnaire was presented to the children to examine whether animistic thinking regarding the dummy would be exhibited. Subjective ratings of valence were inquired from the children to examine how they felt when watching the stimuli.

Results were contrary to expectations. The study did not provide evidence of perceived gaze direction of animate and inanimate models affecting frontal EEG asymmetry as hypothesized in children of either age group. The children in both age groups exhibited animistic thinking regarding the dummy, but there was no difference found in the amount of animistic thinking between age groups. Valence ratings indicated that watching both models and gaze directions was fairly pleasant.

Many factors may have contributed to the results of this study. Studies suggest that the mental and neural processing of gaze direction develops with age. The development of these processes in the studied age groups may be at a stage where gaze direction does not yet activate the affective-motivational neural systems efficiently. It is also unclear to what extent methodological issues may have contributed to the results of this study. Longitudinal research should be executed to provide more information regarding the effect of gaze direction on frontal EEG asymmetry during development, taking contributing individual factors into account.

INTRODUCTION

Eye gaze plays an important role in social interaction. For instance, a sudden shift in the gaze direction of the person you are talking to might tempt you to look in the same direction to find out what caught the other person's attention. Gaze serves several social functions such as providing information, regulating interaction, expressing intimacy, exercising social control and facilitating service or task goals (Patterson, 1982). It has been suggested that in the course of evolution the role of social gaze has evolved to a more sophisticated level in humans and other primates compared to other species (Emery, 2000).

The morphology of the human eye makes it easy to discriminate what direction the other person is looking at (Kobayashi & Kohshima, 1997). Studies suggest that perceived gaze direction affects us in several ways (for a review, Senju & Johnson 2009). Perceived eye gaze has been proposed to affect cognition and to induce physical responses in the body. Direct gaze is detected faster among averted gaze distracters than averted gaze among direct gaze distracters (Conty, Tijus, Hugueville, Coelho, & George, 2006; von Grünau & Anston, 1995). Perceived direct gaze has been associated with faster gender discrimination (Macrae, Hood, Milne, Rowe, & Mason, 2002) and detection of identity (Hood, Macrae, Cole-Davies, & Dias, 2003). Perceived direct gaze has also been found to capture visuospatial attention (Senju & Hasegawa, 2005). On the contrary, perceived averted gaze has been found to induce a shift of attention to the direction looked at by the other person (Frischen, Bayliss, & Tipper, 2007). Perceived direct gaze has been linked to increased levels of arousal in adults (Helminen, Kaasinen, & Hietanen, 2011; Nichols & Champness, 1971) and changes in heart rate (Akechi et al., 2013). Adams and Kleck (2005) have reported findings of perceived direct gaze enhancing the perception of approach-oriented emotions and perceived averted eye gaze enhancing the perception of avoidance-oriented emotions in undergraduate students. Studies suggest that viewing direct and averted gaze affect brain activity in different ways. For example, when viewing an attractive unfamiliar face, brain activity in the ventral striatum increases when eye contact is made and decreases when the other person's eye gaze is directed elsewhere (Kampe, Frith, Dolan, & Frith, 2001).

Advances in functional neuroimaging and infant behavioral studies have enabled the study of gaze from the perspective of developmental cognitive neuroscience (Senju & Johnson, 2009). The present study examines whether gaze direction influences neural approach-avoidance responses in children and whether it would make a difference to these responses if children viewed the face of a human or a dummy. In children, the developmental stage of neural and mental eye gaze processing, the stage of social development and also the ability to distinguish the animate from the inanimate may have an effect on whether or not and in which situations these responses are elicited.

Gaze processing in children

A large number of studies on gaze processing have been carried out in adults. Gaze processing in children has been less explored. There is a growing number of studies on gaze processing in infants. Cross-sectional studies have produced information regarding the effect of gaze at different ages in childhood. There is evidence of eye gaze affecting children from early infancy onwards. Newborns have been shown to look longer at a photo with a face with eyes open than with eye closed (Batki, Baron-Cohen, Wheelwright, Connellan, & Ahluwalia, 2000). Direct and averted gaze can be discriminated from birth, and newborns have been found to view faces with direct rather than averted gaze (Farroni, Csibra, Simion, & Johnson, 2002). It has been demonstrated that infants at the age of three months shift attention to the same direction an adult is looking at (Hood, Willen, & Driver, 1998). As with adults, direct gaze has been found to facilitate face recognition in four-month-old infants (Farroni, Massaccesi, Menon, & Johnson, 2007) and children at the age of 6–11 years (Smith, Hood, & Hector, 2006). Direct gaze has found to be detected faster than averted gaze in 9–14 year-old children (Senju, Hasegawa, & Tojo, 2005).

There is evidence of gaze direction processing developing with age. Doherty, Anderson and Howieson (2009) propose that the ability to judge where someone is looking arises approximately at the age of three and develops near to adult level by the age of six. Doherty et al. (2009) suggest that children at the age of three may realize that eye gaze provides information of other’s minds, which motivates them to learn to discriminate eye gaze more accurately. Vida and Maurer (2012) compared the ability to discriminate gaze direction between 6- and 8-year-olds and adults. They found that 6-year-olds perceived gaze direction as direct over a wider horizontal range of position (~8°) than 8-year-olds and adults. The experimenters suggest that 6-year-olds may be less sensitive to the social signals associated with averted gaze. It has been suggested that school-aged children can process and detect shifts in eye gaze as adults (Mosconi, Mack, McCarthy, & Pelphrey 2005).

At the moment, the precise neural mechanisms and developmental processes involved in eye gaze processing are unclear. There is evidence of eye gaze direction affecting brain activity from a young age (Farroni et al., 2002). Regarding eye contact specifically, different kinds of hypotheses of the mechanism behind the processing of eye contact have been suggested (Senju & Johnson, 2009). One view is that there may be an innate module specialized in the detection of gaze direction guiding the further learning (Baron-Cohen, 1995). Another view is that eye gaze becomes important through experience and learned reward value (Hood et al., 2003). A third view suggests that postnatal experience interacts with an innate architectural bias (Senju & Johnson, 2009).

Although studies have demonstrated that adults and infants show many similar behavioral reactions to eye gaze, there is evidence of somewhat differential brain activity in response to gaze (for reviews on infant brain activity in response to gaze, see Grossmann & Johnson, 2007; Hoehl et al., 2009). Grossmann and Johnson (2007) suggest that cortical structures involved in the perception of gaze direction are perhaps only partially functioning in infancy and may not be fully differentiated from face processing. In adults, the superior temporal sulcus region is involved in perception of eye gaze direction (Allison, Puce, & McCarthy, 2000), whereas the fusiform gyrus appears to discriminate gaze direction best in infants (Johnson et al., 2005). Infants at the age of four months have been shown to exhibit a more negative infant N170 ERP-component to direct gaze than averted gaze indicative of enhanced neural processing of direct gaze (Farroni et al., 2002). By the age of five, this enhancement is no longer seen in neural processing and neither is it seen in adulthood (Grice et al., 2005). This is hypothesized to be due to the growth of social relevance of averted gaze. However, mental and neural processing of gaze and face may not be fully developed to adult level in later childhood either. Kylliäinen, Braeutigam, Hietanen, Swithenby, and Bailey (2006) studied children at the age of 8–11 years with magnetoencephalography (MEG) and found that even in children at this age, neural mechanisms underlying face processing may be less specialized than in adults.

These studies demonstrate that many phenomena linked to adult eye gaze processing on a behavior level can already been seen at an earlier stage of life, at least to some extent. Yet, the neural mechanisms behind eye gaze processing during development are unclear. Studies involving children are limited and have often been conducted in specific age groups. More research is needed in this area of study.

The approach-avoidance motivational brain system in relation to gaze

The direction of gaze can be seen as a way to regulate interaction (Kleinke, 1986). For instance, someone making eye contact may be interpreted as attempting to initiate interaction, signaling approach motivation. On the other hand, someone looking away may be seen as attempting to withdraw from interaction, signaling avoidance motivation. On a neural level, approach- and avoidance-related motivation has been associated with asymmetric frontal EEG activity (for a review, Harmon-Jones, Gable, & Peterson, 2010). Generally, approach-related motivation and positive affect have been associated with relative left-sided frontal cortical activity, whereas avoidance-related motivation and negative affect have been associated with relative right-sided frontal cortical activity. This kind of asymmetric activity of the brain has been demonstrated to take place from infancy onwards (e.g. Buss et al., 2003; Davidson & Fox 1989). In a study by Fox et al. (1995), 4-year-olds children who showed greater relative left-sided frontal activation of the brain were more likely to initiate social interaction and display positive affect, whereas children with greater relative right-sided frontal activation were more likely to display social withdrawal.

It has been reported that seeing another person's direct versus averted gaze induces frontal EEG asymmetry (Hietanen, Leppänen, Peltola, Linna-aho, & Ruuhiala, 2008). In the mentioned study, perceived direct gaze elicited relative left-sided frontal EEG activity, whereas perceived averted gaze elicited relative right-sided frontal EEG activity. These results suggest that perceived direct gaze may induce approach-related motivation, whereas perceived averted gaze may induce avoidance-related motivation. In another study, Pönkänen, Peltola, and Hietanen (2011) found that perceived averted gaze elicited relative left-sided frontal EEG activity, but perceived direct gaze elicited greater relative left-sided frontal EEG activity than perceived averted gaze. In a third similar study, gaze direction did not have an effect on frontal EEG asymmetry (Pönkänen & Hietanen, 2012). The experimenters suggest that differences in experimental procedure and design may have caused the contradictory results. All of the mentioned studies were conducted with adults. There are few studies concerning children in this area of research. Kylliäinen et al. (2012) investigated the effect of perceived direct gaze on affective-motivational neural responses with typically developing children and children with autism spectrum disorders. In typically developing children (age range 11–14 years), open eyes elicited greater relative left-sided frontal EEG activity associated with approach-related motivation than shut eyes and wide-open eyes.

In the studies by Hietanen et al. (2008) and Pönkänen et al. (2011), the effect of perceived gaze direction on frontal EEG asymmetry was only observed when facing a real person. Pictures of faces with direct and averted gaze did not induce the same effect. The experimenters of these studies suggest that this difference in results might be related to mentalizing processes and experienced public self-awareness in the presence of a real person. Perceived direct gaze has been found to elicit higher ratings of public self-awareness in live than in picture condition (Hietanen et. al., 2008; Pönkänen et al., 2011).

Another type of evidence of the effect of live facial stimuli compared to other presentation modes comes from the study by Pönkänen et al. (2008). They compared event-related potential responses to a human face with direct gaze to a dummy face with direct gaze. Participants were presented with the faces of a human and a dummy, and also with pictures of these. There was a more negative shift in the early posterior negativity (EPN) amplitude in response to the human face than to the face of the dummy. This effect was prevalent only in the live condition and not when stimuli were presented as pictures. Pönkänen et al. (2008) suggest that this indicates that a live human face intensifies early visual processing and elicits affective processes more than a picture of a face, because the human physically present can be seen as potentially interacting.

Interestingly, Kampe, Firth and Frith (2003) demonstrated that seeing another person's direct gaze activates the same regions in the brain that activate when mentalizing. Mentalizing or having a theory of mind (ToM) refers to the ability to attribute mental states, such as intentions, goals and desires, to another person (e.g. Wellman, 1992). Emery (2000) has reviewed research on gaze processing in humans and in animals. Studies indicate that making mental attributions based on gaze may be limited to humans and possibly the great apes. The ability to mentalize has been suggested to emerge in childhood as a part of social development.

Social development and gaze

It has been suggested that infants from birth show sensitivity to social interaction. The attainment of eye contact creates circumstances of interaction between two people (Kleinke, 1986) and a ground for further social development. Infants show preference for face-like patterns (for a review, Johnson, 2005). As mentioned earlier, studies also indicate that infants may have a preference for faces that allow eye contact (Batki et al., 2000). In a study by Symons, Hains, and Muirir (1998) an adult interacted with 5-month-old children with eye contact and with slightly averted gaze. They found that the attention and smiling of children decreased in the averted gaze condition. The emotional expressions of an infant and caretaker enable the regulation of interaction (Tronick, 1989).

Infants engage in face-to-face interactions (Striano & Bertin, 2005). Before the age of two, dyadic (person-person) interactions extend to triadic (person-object-person) interactions. As mentioned earlier, the ability to shift attention to the direction another person is looking at can be seen in infants from the age of 3 or 4 months (Hood et al., 1998). This ability enables sharing experiences of surroundings with another person. This triadic type of interaction is often referred to as joint attention (e.g. Carpenter, Nagell, & Tomasello, 1998). It can be viewed as an important milestone in social and cognitive development, e.g. in the acquisition of language (Mundy et al., 2007).

The development of a theory of mind or mentalizing is another important part of the social development in children. As mentioned earlier, theory of mind refers to the ability to attribute mental states, such as intentions, goals and desires, to another person (e.g. Wellman, 1992). Recent studies have shown evidence of abilities involving theory of mind in infants (for a review, Sodian, 2011). There is evidence of infants showing mentalizing abilities based on perceived gaze direction. For example, Phillips, Wellman, and Spelke (2002) showed that 1-year-olds can use the information of an adult's direction of gaze and emotional expression to predict which of two objects an adult would grasp. Much research has focused on the development of theory of mind in 3- to 5-year-olds, and how children at this age range become increasingly skilled in their mentalizing abilities

(Samson & Apperly, 2010). Children at the age of four are able to read mental states from direction of gaze from pictures (Baron-Cohen, Campbell, Karmiloff-Smith, Grant, & Walker, 1995). It has been suggested that these higher order mentalizing abilities continue to develop beyond childhood (Beauchamp & Anderson, 2010).

The animate-inanimate distinction

It is commonly considered that the human tendency to follow gaze is closely related to the attribution of mental states to the person looked at (Johnson, Slaughter, & Carey, 1998). Infants follow the gaze of another person (Hood et al., 1998), but some studies have shown that infants also follow the gaze of non-human agents (Johnson et al., 1998; Meltzoff, Brooks, Shon, & Rao, 2010). This raises the question of whether or not infants and children distinguish the gaze of a human from non-human agents and give the gaze of a human a unique social significance or whether gaze following happens in the absence of mental attributions in early stages of life.

Animistic thinking may affect how the perceived gaze of inanimate agents is mentally and neurally processed. The animate-inanimate distinction refers to the distinction between living entities (people and animals) from non-living entities (e.g. Opfer & Gelman, 2010). It has been proposed that children may exhibit animistic thinking, e.g. attribute human properties such as mental states to inanimate agents. The classic study of animism by Jean Piaget (1929) proposes that there are four stages in the development of animate-inanimate distinction: stage 1 (4–6 years), where children believe everything that is active, undamaged or useful is alive, stage 2 (6–8 years), where children believe everything that moves is alive, stage 3 (8–12 years), where children believe that everything that moved by itself is alive, and stage 4 (12 years–), where children distinguish correctly between the animate and inanimate.

Subsequent studies have shown that young children do indeed show some animistic type of thinking, but dispute at what age animistic thinking takes place, in what ways animism presents itself and what the reasons for this type of thinking may be. Numerous studies have focused on children under school-age, who have been demonstrated to show increasing ability to distinguish attributes of the animate from the inanimate (Bullock, 1985; Jipson & Gelman 2007; Margett & Witherington, 2011; Saylor, Somanader, Levin, & Kawamura, 2010). However, the ability to distinguish the animate from the inanimate can be seen in some forms as early as infancy (Legerstee, 1992; Rakison & Poulin-Dubois, 2001). There is evidence of infants reacting to and treating people differently compared to objects. In the study by Legerstee, Pomerleau, Malcuit, and Feider (1987), infants were shown a traditional doll and a person. They found that the infants smiled and vocalized more at the person in comparison to the doll. In another study, infants were shown mouth openings and tongue protrusions modeled by an adult and simulated by objects (Legerstee, 1991). The infants congruently imitated what the adult did, but did not reproduce the gestures simulated by the object congruently. There is also evidence of infants showing different reactions to the shift of gaze or head turn of human and inanimate object. Legerstee and Berillas (2003) examined whether 12-month-old infants would share attention with a human and a life-sized doll. In the human condition, the human model first established eye contact with the infant by calling the infant by name, and thereafter oriented her head to another direction to look at a toy. In the doll condition, bells were played to get the child’s attention, and after that the experimenter (out of the infant’s sight) moved the doll so that it appeared to “look” at a toy. Results showed that infants followed the head-turn cues of both the human and doll models. However, infants exhibited longer gazes towards the human model, directed longer positive affect to the human model, showed more model-toy-model gaze shifts with the human model, and vocalized more at the human model.

Okumura, Kanakogi, Kanda, Ishiguro, and Itakura (2013) showed 12-month-olds infants videos in which either a human or a robot shifted gaze from straight forward to one of two objects. In this study, infants followed the gaze of both model types. However, infants gazed longer at the object cued by the human model. The experimenters also found that when infants were shown the two objects a later phase of the experiment, infants looked at the uncued object longer when they had seen a video with a human compared to a robot. When children were given the chance to choose an object of preference, they preferred the cued over the uncued object when they had seen the video with a human compared to a robot. The experimenters suggest that human gaze may have a unique effect on infants’ object processing and learning.

According to a review by Hamlin and Baron (2014), infants attribute human or animal properties to things that look like, move like, act like, and interact like agents. Opfer and Gelman (2010) classify properties distinguishing the animate from the inanimate more broadly to featural (e.g. faces and the eyes) and dynamic properties (e.g. self-propelled movement). Opfer (2002) studied how children and adults attribute biological and psychological capacities to novel entities moving either goal-directed or aimlessly. In all age groups, both biological and psychological properties were ascribed to entities that appeared to move in a goal-directed manner. In children, both biological and psychological capacities were attributed to the entities in approximately the same way, whereas in adults, biological capacities were attributed to the entities more than psychological ones. Opfer suggests that other factors than goal-directed movement may affect whether something is judged sentient or not.

The resemblance of an inanimate object to an animate object may affect the ability to distinguish these two from each other. In a study by Beran, Ramirez-Serrano, Kuzyk, Fior, and Nugent (2011), children aged 5–16 years ascribed many human characteristic to robots. Jipson and Gelman (2007) noted that although children were capable of making clear distinctions between the animate and inanimate concerning biological attributes in their study, distinctions regarding the psychological attributes were more difficult. Five-year-olds and even adults were found to rely on facial features in order to make psychological and perceptual judgments. Jones, Smith, and Landau (1991) examined how children classify objects with and without eyes, and found that they tended to classify them on different basis. These studies provide evidence of the significance of the face and eyes in the animate-inanimate distinction.

Aims of the study

The aim of this study was to investigate whether perceived gaze direction (direct versus averted) influences neural approach-avoidance responses in children and whether it would make a difference if the children viewed the face of a human or a dummy. In the present study, two age groups (5- and 7-year-olds) were compared to examine the effect of age on these neural responses. Possible differences in the amount of animistic thinking between the age groups were expected to affect the neural responses.

Based on previous studies in adults, it was expected that the perceived direct gaze of a human would elicit left-sided frontal EEG asymmetry, and the perceived averted gaze of a human would elicit smaller left-sided frontal EEG asymmetry or right-sided frontal EEG asymmetry in children of both age groups. Based on research on animism, it was expected that the 5-year-olds would exhibit animistic thinking and attribute human properties to a dummy. It was expected that the perceived gaze direction of the dummy would therefore elicit similar neural responses as the perceived gaze direction of the human in the 5-year-olds. Studies indicate that animistic thinking decreases during the preschool years and therefore it was expected that only the perceived gaze direction of the human would influence neural approach-avoidance responses in the 7-year-olds.

Regarding the EEG activity, the power in the alpha band (6–9 Hz, 6–12 Hz, 8–13 Hz) from the left and right frontal channels (F4/F3 and F8/F7) was recorded during stimulus presentation. The occurrence and the extent of animistic thinking were examined with an animism questionnaire (Appendix 1). Subjective ratings of valence were also inquired from children to examine how pleasant or unpleasant the children felt when watching the stimuli.

METHODS

Participants

Thirty-four children participated in the experiment during December 2009–May 2010 at the Human Information Processing Laboratory, School of Social Sciences, University of Tampere. Six additional participants were excluded from the data analysis due to restlessness, excessive movements or technical error during the experiment. There were sixteen 5-year-old (mean age = 5.15 years, range, 5.08–5.27 years) and eighteen 7-year-old (mean age = 7.10 years, range 7.00–7.17 years) participants. Both genders were represented in the 5-year-olds' group (7 male, 9 female) and the 7-year-olds' (7 male, 11 female) age groups. Households of possible participants were contacted by a letter of invitation. Invitation was sent to random samples of children born in 2000 and in 2002 in between the months of November and March in the Tampere region. Addresses were acquired from the Finnish Population Register Centre. Participation was limited to typically developing children. All families interested in taking part were recruited and received a small gift for participating. A verbal consent was obtained from the child participants and a written consent was obtained from guardians.

Stimuli

Two young females and a dummy model served as facial stimuli (Figure 1). Direction of gaze was either direct or averted (right or left). The dummy comprised of a realistic-looking human-sized torso and head. A mechanism was built behind the dummy's head to move the direction of eyes. Only the head and upper body of the models were presented to the child during data collection. The two experimenters served as the human stimuli with half of the children seeing one and half the other. The eye level of the children and models was matched so that eye contact was easy to attain. The facial expression was neutral and blinking avoided. The stimuli were presented through a rectangle-shaped aperture (40x32 cm) in the middle of a black panel, which was covered with a curtain between trials. The child was seated at a 70 cm distance from the aperture. The stimuli were roughly at an additional 30 cm distance from the aperture and thus one meter apart from the child.

Experimental procedure

Stimuli were presented in six blocks, all blocks consisting of six trials. Alternate blocks showed either the human model or the dummy model. The presentation order of blocks was counterbalanced between the children in both age groups. All blocks included trials with direct and averted gaze (right and left). Gaze presentation order was randomized with the condition that a maximum of two gazes in the same direction were shown one after another in each block. The children's behavior was monitored throughout the experiment with the aid of a video camera. A maximum of two additional trials per block were presented whenever necessary, e.g. in cases where the child moved, spoke, vocalized some other way, or lacked attention to the stimulus. In sum, the children were shown 1) a dummy model with direct gaze 2) a dummy model with averted gaze 3) a human model with direct gaze, and 4) a human model with averted gaze. In each condition, a minimum of nine trials were presented.

The stimuli were shown through the aperture for approximately 4 seconds per trial. Between trials, the experimenter covered the aperture with a black curtain to hide the stimulus as quickly as she could. The experimenter was out of the child's sight during the EEG data acquisition. The experimenter sat in front of a computer hidden behind the panel. A NeuroScan software operated on PC was used to manage trial timings. The experimenter had headphones on, and from the experimenter's click of a mouse, a sound followed two seconds later informing her to lift the curtain and start the trial. Five seconds later another sound guided her to lower the curtain and end the trial. It took approximately 1 second to lift the curtain and therefore the actual stimulus presentation time was approximately 4 seconds. To ensure a long enough inter-stimulus-interval, another sound informed the experimenter when 20 seconds had passed from the end of each trial and a new trial could be initiated. Stimuli were displayed when the child appeared quiet, still and attending towards the correct direction. The behavior of the child was observed with the aid of video camera. The video camera was out of the child's sight and the child was unaware of its presence. The experimenter verbally repeated instructions to the child between trials when necessary. A short pause was held after these instructions to prevent the influence of speech on the data collection of the next trial.

Participating in the experiment was made as comfortable and pleasant for the child as possible. After arriving to the laboratory, the course of the experiment was thoroughly described to the child in an age-appropriate way. This was done with the help of pictured cards illustrating the different phases of procedure. These included preparing for the physiological measurements (1), watching two models (2), answering questions (3) and receiving a gift for participating (4).

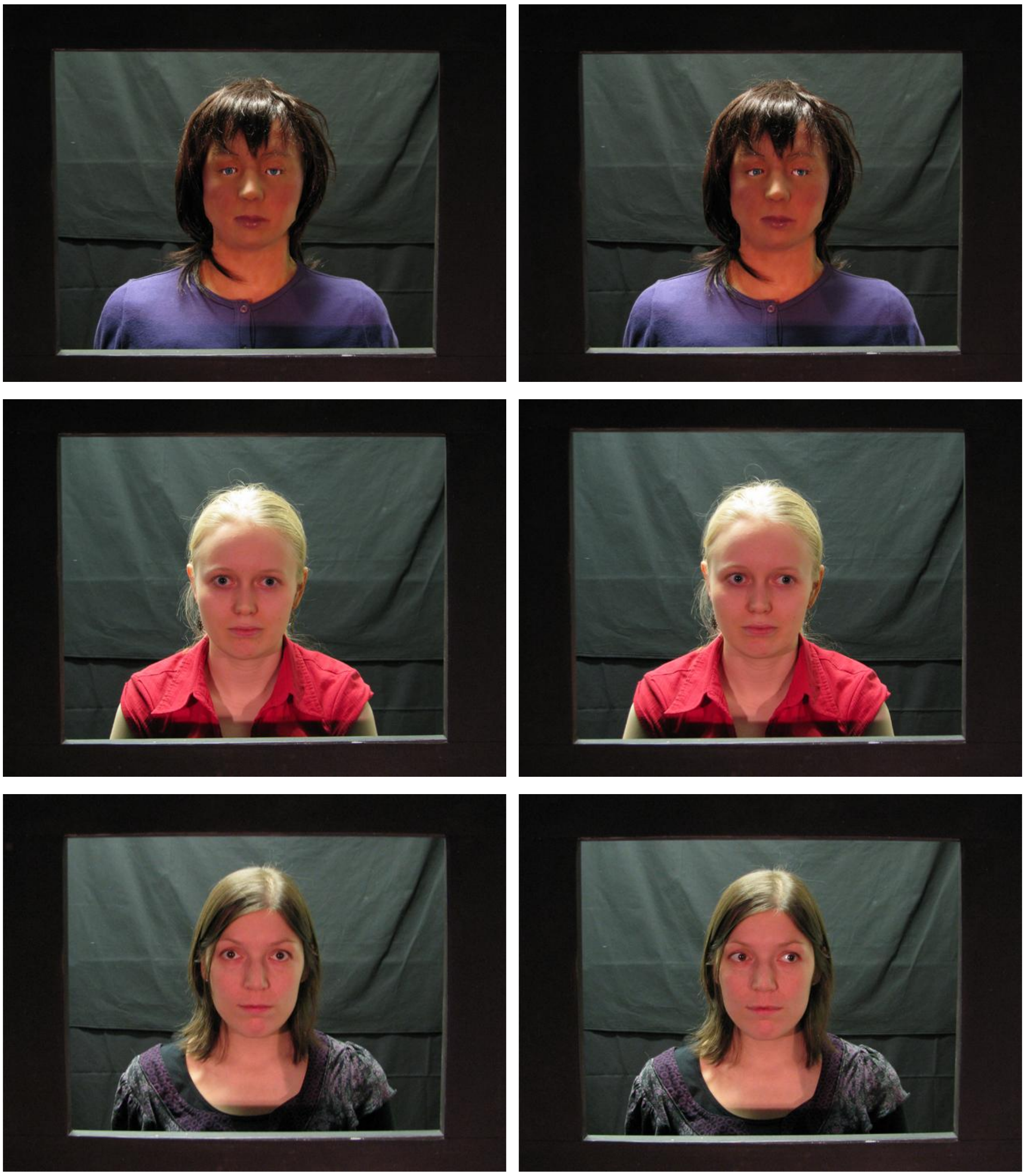

Figure 1. Top: dummy model. Middle: human model 1. Bottom: human model 2.

During the preparations for the physiological measurements, each child was offered the opportunity to watch cartoons for a pass of time. The child's parent was primarily allowed to be present from arrival until data collection. In cases where the child required the presence of parent during data collection, e.g. if the child felt anxious, the parent was seated in the back of the laboratory out of the child's visual field.

The child was introduced to the two models, the dummy which was referred to as "Laura" and the human model by her name. The child was shown that the dummy's eyes moved. The dummy was placed on top of a chair and the child could see it had neither legs nor arms. The dummy was not at any point referred to as anything inanimate (e.g. dummy, doll) and the mechanism making the eyes move was not showed or explained to the child.

After preparations, the models were hidden behind the black panel and curtain. The child was instructed to concentrate on watching the faces of the models revealed from behind the curtain. The child was not told which model and gaze direction to expect at each lift of the curtain. The child was seated and instructed to remain as calm and relaxed as possible. To motivate the child and inform him or her of progression made during the physiological measurements, a reward system was used. Short pauses were held after each block during which the experimenter awarded the child with stamps and further instructed the child if needed. Beverages were served half way through the experiment to keep the child's energy level up. The data gathering lasted approximately 30 minutes.

After physiological measurements, the child was asked to answer questionnaires. The child was first familiarized with a 5-point Self-Assessment Manikin scale (Bradley & Lang, 1994) and its answering system. Through the aperture, the child was once again, one at a time, shown each of the models with direct and averted gaze, and asked to evaluate how he or she felt (unpleasant to pleasant on a 5-point scale) when looking at the stimulus. The order of model appearance was counterbalanced between children. First one model was shown with direct and averted gaze in randomized order and then the same process was repeated with the other model.

The second questionnaire concerned animistic thinking (Appendix 1). The questionnaire was designed by the experimenters in order to study the occurrence and extent of animistic thinking in children regarding especially human social and mental aspects. The child was presented with either the human or the dummy with a direct gaze, and afterwards asked to answer questions expressed by the experimenter. The dummy and human model presentation order was counterbalanced.

Acquisition of the EEG data

Physiological measurements included the electroencephalogram (EEG), electrocardiogram (ECG) and skin conductance response (SCR). Only EEG results are reported here. Continuous EEG signal from the frontopolar (FP1, FP2), midfrontal (F3, F4), lateral frontal (F7, F8), central (C3, C4) parietal (P3, P4) and occipital (O1, O2) sites was collected. The central Cz served as a reference to the signal. Horizontal and vertical eye movements were recorded. Horizontal eye movements were measured by electrodes placed at the outer canthi of each eye. Electrodes above and below the child's left eye were placed to measure vertical eye movements. Impedances were kept as low as possible with the aid of gentle skin abrasion and electrode paste. Impedances of the channels F3, F4, F7 and F8 were below 5 kΩ. The EEG signal was amplified with SynAmps amplifiers with a gain of 5000 and a 1 to 200-Hz-band-pass filter. A 50-Hz notch filter was enabled. The continuous signal was digitized at 1000 Hz and stored on a computer for off-line analyses.

Data analysis

A regression-based blink reduction algorithm was used to eliminate blink artifact from the continuous EEG signal (Semlitsch, Anderer, Schuster, & Presslisch, 1986). The gazing behavior of each child during the data gathering was recorded on DVD. The child's gazing behavior during each trial was categorized as follows: (1) looking at stimulus for the entire period of stimulus presentation, (2) looking at stimulus for some time or (3) not looking at stimulus. Trials where the child did not look at stimuli were excluded from further analysis. In addition, other reasons for trial disqualification consisted of the child's movement, speech or other vocalization, and environmental sounds detected during the experimental procedure. The maximum number of accepted trials from each child per model and gaze direction was nine. When the number of qualified trials was at least six for each of the four conditions, the data of that child were further analysed.

Possible artifacts were inspected visually and eliminated. Selected time periods were segmented into eight 1.024-ms epochs with 50% overlap between adjacent epochs. Of these epochs the spectral power was calculated using the Fast Fourier Transform with a 10% Hanning taper. Power density values (μV^2) were calculated to attain the average power spectra within each condition in selected frequency band areas.

Frontal asymmetry was examined by comparing the frontal EEG activity of the left and right hemispheres in the alpha frequency band. Alpha power (for a review, Bazanova & Vernon, 2014) has been found to be inversely related to regional brain activity in behavioral tasks (Davidson, Chapman, Chapman, & Henriques, 1990). The analyses focused on three alpha bands: 6–12 Hz, 6–9 Hz and 8–13 Hz. The adult mean alpha frequency is 10 Hz, and it is reached at the age of 10 (Niedermeyer & Lopes da Silva, 1999). The alpha band of 8–13 Hz has been used in a similar study with adults (Hietanen et al., 2008), and was therefore chosen for analysis. The alpha range has been found to vary with age with younger children showing lower alpha peaks than adults (Marshall, Bar-Haim, & Fox, 2002). The range of 6–9 Hz is a commonly used frequency band with children, and thus also chosen for analysis. However, Marshall et al. (2002) suggest that an extended frequency band may better capture spectral peaks after the age of four. Boersma et al. (2011) found that the mean alpha peak for 7-year-old children is approximately 8.5 Hz. To ensure capturing the oscillating alpha peak in two different age groups, a wide-band range of 6–12 Hz was also used.

Power density values in these frequency bands were ln-transformed to normalize distributions. The analyses focused on the electrode pairs F4/F3 and F8/F7, which have been used in previous frontal EEG asymmetry research (Hietanen et al., 2008; Verona, Sadeh, & Curtin, 2009). Asymmetry scores were obtained by subtracting the left site ln-transformed power density values from the from the right site ln-transformed power density values (ln F8-ln F7 and ln F4-ln F3) (Allen, Coan, & Nazarian, 2004). Positive asymmetry scores reflect relative left-sided frontal EEG activity (indicative of approach), whereas negative asymmetry scores reflect relative right-sided frontal EEG activity (indicative of avoidance). The analysis of variance (ANOVA) was used to statistically analyse the asymmetry scores, and also the subjective ratings of valence. Further analyses were performed with t-tests.

The animism questionnaire was scored by calculating the sum of yes-answers for each child separately for answers regarding the human and dummy. Each yes-answer meant that the child connected a human psychological attribute to the model questioned about. The reliability of the measures used was examined with Cronbach alpha. The Cronbach alphas to the answers regarding the human model were $\alpha=.67$ (5-year-olds), $\alpha=-.19$ (7-year-olds), $\alpha=.50$ (age groups combined). The Cronbach alphas to the answers regarding the dummy model were $\alpha=.82$ (5-year-olds), $\alpha=.84$ (7-year-olds) and $\alpha=.83$ (age groups combined). In most cases, the reliability was appropriate, $\alpha >.60$. For the human model, there were zero variance items, which provides an explanation as to why the alpha was below .60. It was expected that children would connect human properties to the human model, and therefore the measure used here was considered appropriate to use. The analysis of variance was used to statistically analyse the animism questionnaire. Further analyses were performed with t-tests.

The animism questionnaire included a question where the children were asked whether or not they believed the human and the dummy were alive or not (question 10) and what they based their answers on. In addition to the analysis regarding the animism questionnaire described earlier, this question was analysed separately in order to gain information on whether there would be a difference between age groups in the belief of whether the human and the dummy are alive. The χ^2-test was used as the analysis method for this specific question. Various answers were given to why the model types were thought to be alive or not, and these answers were grouped. Grouped answers were not statistically analysed because the assumptions of the χ^2-test (under 20% of expected frequencies under 5 and the expected count over 1) were not fulfilled.

RESULTS

Frontal EEG asymmetry data

The mean EEG asymmetry scores grouped by age are presented in Table 1 for the electrode pair F4/F3 and Table 2 for the electrode pair F8/F7. The asymmetry score data from the frontal electrode pairs F4/F3 and F8/F7 were analysed using three-way analyses of variance with model type (human versus dummy) and direction of gaze (direct versus averted) as within-subjects, and age (5- versus 7-year-olds) as a between-subject factor. Analyses were separately conducted for the frequency bands of 6−12 Hz, 6−9 Hz and 8−13 Hz.

Table 1.

Mean EEG asymmetry scores and standard deviations in parenthesis for the electrode pair F4/F3

	Model and gaze direction			
Frequency band and age group	Human direct	Human averted	Dummy direct	Dummy averted
6–12 Hz				
5-year-olds	0.03 (0.10)	0.05 (0.11)	0.07 (0.14)	0.05 (0.12)
7-year-olds	0.01 (0.12)	0.03 (0.14)	0.04 (0.14)	-0.02 (0.11)
6–9 Hz				
5-year-olds	0.03 (0.12)	0.04 (0.13)	0.07 (0.17)	0.03 (0.14)
7-year-olds	0.01 (0.12)	0.02 (0.15)	0.03 (0.17)	-0.03 (0.13)
8–13 Hz				
5-year-olds	0.05 (0.09)	0.08 (0.11)	0.08 (0.11)	0.09 (0.12)
7-year-olds	0.02 (0.13)	0.05 (0.14)	0.06 (0.12)	0.00 (0.13)

Table 2.

Mean EEG asymmetry scores and standard deviations in parenthesis for the electrode pair F8/F7

	Model and gaze direction			
Frequency band and age group	Human direct	Human averted	Dummy direct	Dummy averted
6−12 Hz				
5-year-olds	0.05 (0.14)	0.09 (0.10)	0.05 (0.11)	0.07 (0.10)
7-year-olds	0.00 (0.12)	0.03 (0.15)	0.02 (0.10)	-0.03 (0.11)
6−9 Hz				
5-year-olds	0.02 (0.15)	0.06 (0.12)	0.03 (0.12)	0.04 (0.11)
7-year-olds	-0.01 (0.11)	0.01 (0.17)	0.01 (0.10)	-0.04 (0.11)
8−13 Hz				
5-year-olds	0.09 (0.15)	0.13 (0.11)	0.10 (0.12)	0.13 (0.11)
7-year-olds	0.04 (0.17)	0.06 (0.15)	0.04 (0.13)	-0.01 (0.15)

Frequency band 6−12 Hz

There were no main effects found for either of the electrode pairs. A significant interaction between gaze direction and model type was found for electrode pair F4/F3, $F(1, 32) = 4.53$, $p < .05$, $\eta^2 = .12$ (Figure 2). Further analyses indicated that none of the possible pairwise comparisons were significant. When the effect of gaze direction (direct versus averted) was separately analysed for each model type (human and dummy), the results showed that gaze direction had no effect on EEG asymmetry scores for either model. Also, when the effect of model type was separately analysed for each gaze direction, the results showed model type had no effect on EEG asymmetry scores for either gaze direction.

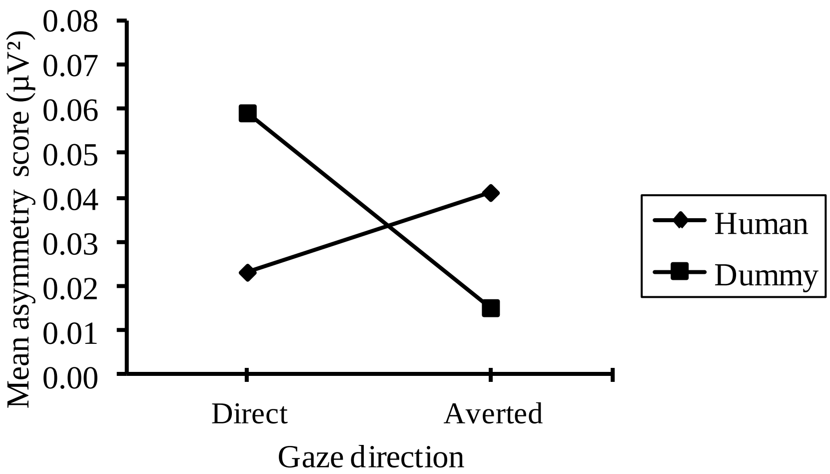

Figure 2. Mean asymmetry scores for the electrode pair F4/F3 averaged across age groups in the frequency band of 6–12 Hz.

Frequency band 6−9 Hz

Regarding the frequency band of 6–9 Hz, the ANOVA showed no main effects or interactions for either of the electrode pairs.

Frequency band 8−13 Hz

The ANOVA showed no main effect of gaze direction or model type for either of the electrode pairs. Regarding the electrode pair F4/F3, there was a significant interaction found between gaze direction and model type, $F(1, 32) = 4.20$, $p < .05$, $\eta^2 = .12$ (Figure 3). Further analyses indicated that none of the possible pairwise comparisons were significant. Regarding the electrode pair F8/F7, age had a significant effect $F(1, 32) = 4.91$, $p <.05$, $\eta^2 =.13$. The overall mean asymmetry scores were higher in the group of 5-year-olds ($M = 0.11$) than in the group of 7-year-olds ($M = 0.03$).

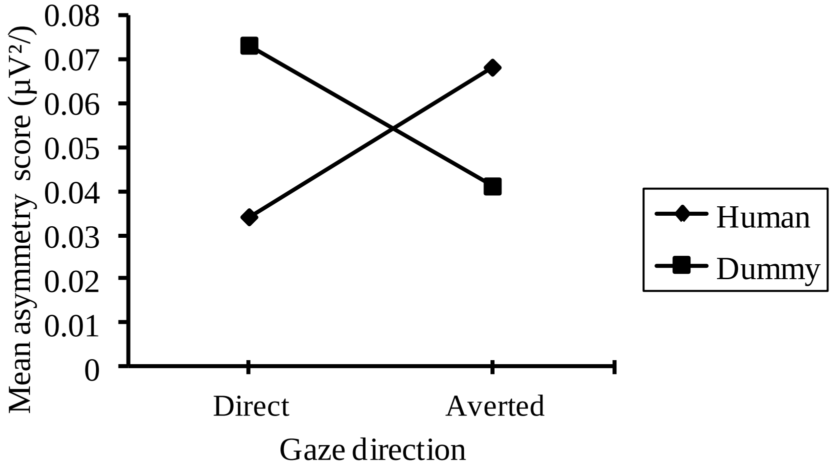

Figure 3. Mean asymmetry scores for the electrode pair F4/F3 averaged across age groups in the frequency band of 8–13 Hz.

The animism questionnaire

The distribution of yes-answers to the animism questionnaire is presented in Appendix 2. The mean scores regarding the animism questionnaire are presented in Figure 4. A two-way analysis of variance was used to analyse the data from the animism questionnaire with model type (human versus dummy) as a within-subject and age (5- versus 7-year-olds) as a between-subject factor. A main effect for model type was found, $F(1, 32) = 63.58$, $p <.01$, $\eta^2 =.67$. The human model was ascribed more human properties ($M = 9.26$) than the dummy model ($M =5.29$) age groups combined. There was no significant interaction between model type and age.

The χ^2-test did not show differences between age groups in response to the question of whether the human or dummy models were alive (animism questionnaire question 10). All of the 7-year-olds and 88% of the 5-year-olds answered that the human model was alive. For the dummy, 11% of 7-year-olds and 13% of the 5-year-olds answered that it was alive.

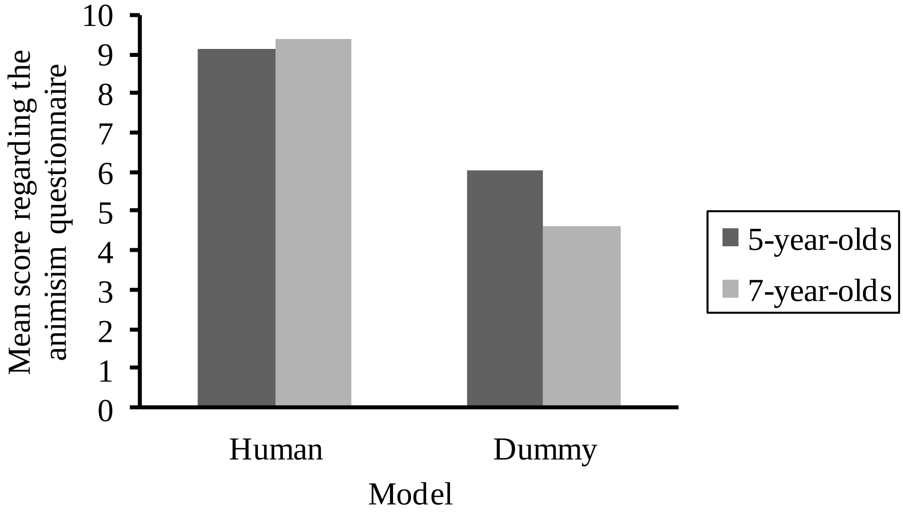

Figure 4. Mean scores regarding the animism questionnaire

Subjective ratings of valence

The mean subjective ratings of valence regarding the stimuli in the two age groups are presented in Table 3. A three-way analysis of variance was used to analyse the valence ratings. The ANOVA indicated no main effects for the valence ratings. However, there was a significant interaction between model type and age, $F(1, 32) = 4.72$, $p < .05$, $\eta^2=.13$. Further t-tests between age groups showed that the 5-year-olds assessed the human model more pleasant ($M = 4.66$) than the 7-year-olds ($M = 4.06$), $t (32) = 2.41$, $p < .05$. For the dummy, there was no significant difference in ratings of valence between age groups. Pairwise comparisons within age groups showed that the 5-year-olds assessed the human model more pleasant ($M = 4.66$) than the dummy model ($M = 3.94$), $t(15) = 2.35$, $p < .05$. Within the age group of 7-year-olds, there was no difference in the valence ratings between the human and dummy model.

Table 3.

Mean ratings of valence

	Gaze directon			
	Human		Dummy	
Age group	Direct	Averted	Direct	Averted
5-year-olds	4.50 (0.63)	4.81 (0.54)	4.13 (1.26)	3.75 (1.70)
7-year-olds	4.06 (0.10)	4.06 (1.11)	4.11 (1.02)	4.11 (0.96)

Note. Scale range from 1 (unpleasant) to 5 (pleasant). Standard deviation in parentheses.

DISCUSSION

The aim of this study was to examine whether seeing direct versus averted gaze influences the affective-motivational neural responses of approach and avoidance in 5- and 7-year-old children and whether it would make a difference to these responses if the children viewed the face of a human or a dummy. The two age groups were compared to examine the effect of age on these responses. Possible differences in the amount of animistic thinking exhibited between the age groups were expected to affect the neural responses. Based on earlier studies in adults, it was hypothesized that the perceived direct gaze of a human would elicit relative left-sided frontal EEG activity (indicative of the motivational tendency to approach) and perceived averted gaze of a human would elicit smaller relative left-sided frontal EEG activity or even relative right-sided frontal EEG activity (indicative of avoidance) in both 5- and 7-year-old children. Furthermore, it was hypothesized that the 5-year-olds would exhibit animistic thinking regarding the dummy to such an extent that they would show similar neural responses to the gaze direction of the dummy and the human. The 7-year-olds were expected to exhibit less animistic thinking than the 5-year-olds. Only the perceived gaze direction of the human was expected to influence neural approach-avoidance responses in the 7-year-olds.

In the experiment, power in the alpha band from the left and right frontal channels (F4/F3 and F8/F7) was measured with EEG. Several alpha bands were tested in the analyses to ensure the capturing of the alpha band applicable to children (6–9 Hz, 6–12 Hz, 8–13 Hz). An animism questionnaire was presented to the children to examine the occurrence and extent of animistic thinking. Subjective ratings of valence were inquired from children to examine how they felt when watching the stimuli.

Frontal EEG asymmetry data

The results of this study did not provide evidence of perceived gaze direction eliciting neural affective-motivational responses in children as hypothesized. There was no clear evidence of perceived gaze direction having an effect on frontal EEG asymmetry in children in either age group with either model type, regardless of which electrode pair channels or alpha band were analysed. The EEG results concerning the gaze direction of the human model are in contradiction with the earlier studies, where adults have been found to show relative left-sided frontal EEG activity in the alpha band (8–13 Hz) in response to another person’s direct gaze and smaller relative left-sided frontal EEG activity in response to averted gaze, or even relative right-sided frontal EEG activity (Hietanen et al., 2008; Pönkänen et al., 2011).

However, the results indicated that the perceived gaze direction of the human in comparison to the dummy could possibly have different effects on frontal EEG activity in children dependent of the alpha frequency band and electrode pair studied. An interaction between gaze direction and model type across age groups was found in the alpha band of 6–12 and 8–13 Hz for the F4/F3 electrode pair. Neural responses appeared to differ from expectations. Surprisingly, in the human condition, direct gaze appeared to induce relative left-sided frontal EEG activity, but averted gaze appeared to induce greater relative left-sided frontal EEG activity. Interestingly, in the dummy condition, the pattern of results appeared to be similar to the results in the live human condition in the study by Pönkänen et al. (2011) with greater relative left-sided frontal EEG activity exhibited in response to direct gaze and smaller relative left-sided frontal EEG activity in response to averted gaze. Also, in the present study the direct gaze of the dummy appeared to evoke greater relative left-sided frontal EEG activity than the direct gaze of the human. In contrast, the averted gaze of the human appeared to evoke greater relative left-sided frontal EEG activity than the averted gaze of the dummy. However, these results should be interpreted with caution because none of the described differences were statistically confirmed in pair wise comparisons.

Several factors may have contributed to the complex results of the present study. The averted gaze of the human may have been seen as more approachable (more relative left-sided frontal EEG activity) than the averted gaze of the dummy, because it is characteristic of humans to be able to look to multiple directions, whereas inanimate objects with eyes (e.g. dolls) usually bear only a direct gaze. This explanation also provides a basis to why the direct gaze of the dummy appeared to evoke greater relative left-sided frontal EEG activity than the averted gaze of the dummy. Furthermore, the age of the models may have affected the results. For example, in the studies by Hietanen et al. (2008) and Pönkänen et al. (2011), participants were adults looking at an adult stimulus. In the present study, children did not look at stimuli of their own size and age-range, but at a human adult and adult-sized dummy. The results of the study by Marusak, Carré, and Thomason (2013) indicate that the perceived facial emotional displays of adults and own-aged stimuli may be processed differently on a neural level in children. Moreover, it is possible that the perceived gaze direction in neutral faces may be processed differently in different age groups. Pönkänen and Hietanen (2012) studied whether gaze direction (direct versus averted) and facial expression (neutral versus smiling) affects neural approach-avoidance responses in adults, but the study did not provide evidence of either. In contrast, Tottenham, Phuong, Flannery, Gabard-Durnam, and Goff (2013) measured the facial corrugator muscle activity of 6–17 year-old children to neutral faces and found that the physiological reaction of children to the neutral faces indicated negative appraisals.

It is also worth noting that several studies suggest that the mental and neural processing of gaze direction develops during childhood. The stage of development of these processes in children may have affected results. For example, there is indication of the accuracy of eye gaze direction judgments enhancing with age (Vida & Maurer, 2012). Higher order mentalizing abilities continue to develop from childhood and adolescence (Beauchamp & Anderson, 2010). Many developmental changes take place in the brain in childhood (Brown & Jernigan, 2012). Kylliäinen et al. (2006) suggest that the neural mechanisms of face and gaze processing are less specialized in 8–11 year-old children than in adults.

The animism questionnaire

All of the 7-year-olds and a vast majority of the 5-year-olds considered the human model to be alive. The majority of children in both age groups knew that the dummy was not alive. Most of the children in both age groups correctly ascribed human properties to the human model. However, children in both age groups ascribed human properties to the dummy as well, but to a smaller extent. The results indicate that 5- and 7-year-old children exhibit some animistic thinking regarding the dummy. Surprisingly, no developmental change between the ages of 5 and 7 in the animate-inanimate-distinction was indicated, although studies indicate that growing children show increasing ability to distinguish attributes of the animate from the inanimate (Bullock, 1985; Jipson & Gelman 2007; Margett & Witherington, 2011; Saylor et al., 2010). The strong resemblance of the dummy to the human may have affected the children's ability to distinguish these two from each other.

However, children may pretend that inanimate objects, such as dolls have human properties in play. It is possible that the children in the present study answered to the animism questionnaire questions using their imagination. Children may have answered that e.g. the dummy could have friends (question 9 in the questionnaire); because one might pretend that the dummy might have friends in imaginary play. When presenting the animism questionnaire, children were asked to answer according to what they really believed and not what could be pretended. However, whether or not children understood and followed this direction is uncertain.

Possible differences in the amount of animistic thinking exhibited between age groups were expected to indirectly affect the neural responses. As mentioned earlier, age did not affect the amount of animistic thinking exhibited regarding the dummy nor did it affect how frontal EEG asymmetry was exhibited in response to gaze direction. The interaction between gaze and model type across age groups in the alpha band of 6–12 and 8–13 Hz for the F4/F3 electrode pair provides some indication that children may process the gaze direction (direct versus averted) of a inanimate dummy and a human model in different ways on neural level. This could be related to the fact that the children did not ascribe human properties to the dummy model to a similar extent as to the human model, but also to the fact that something interpreted as inanimate perhaps surprisingly showed the human ability of movement of the eyes.

Subjective ratings of valence

Subjective ratings of valence indicated that watching all of the four stimulus types was overall fairly pleasant. Perceived gaze direction did not have an effect on ratings. The results differ from previous findings with adults, where the perceived direct gaze of a human in a live situation was evaluated as slightly positive, but less pleasant than the perceived averted gaze of a human (Hietanen et al., 2008). Since the children in both age groups in this study demonstrated relative left-sided frontal EEG activity on average in most of the studied alpha bands and electrode pairs, the subjective ratings of valence are for the most part in concordance with previous studies that generally associate approach-related motivation and positive affect with relative left-sided frontal EEG activity (Davidson & Fox 1989; Harmon-Jones, Gable, & Peterson, 2010).

Although gaze direction did not have an effect on the subjective ratings of valence, age had an effect on the valence ratings given to the models. The 5-year-olds assessed the human stimulus as more pleasant than the 7-year-olds. For the dummy, there was no difference in ratings. Also, the 5-year-olds assessed the human model more pleasant than the dummy, but in the 7-year-olds group there was no difference in assessment between model types. One explanation for these results is that the attention of children during the experiment may not have been actually directed to gaze direction changes, but to more gross changes between models presented (human versus dummy).

On neural level, age did not have an effect on frontal EEG asymmetry in response to the two models. It has been suggested that the valence of stimuli toward which the impulse is directed does not necessarily interrelate to the motivational direction of approach and avoidance, because e.g. anger has been connected to approach motivation (Harmon-Jones et al., 2013). This provides a possible explanation as to why the approach-avoidance motivational neural systems may have been activated in a similar way between age groups even though age group differences were seen in the ratings of valence.

The experimenters' observations of the children's emotional states during data gathering were consistent with subjective ratings of valence to a varying extent. Rating valence may have been a task too difficult for children. It is possible that the subjective ratings of valence may not offer a truthful version of experienced valence.

Methodological issues and future directions

Some methodological factors may have contributed to the results of this study. In another similar study of frontal EEG asymmetry to another person's direct versus averted gaze in adults using live models, gaze direction did not have an effect on frontal EEG asymmetry either (Pönkänen & Hietanen, 2012). The experimenters of that study compared their experimental design to the earlier ones conducted where gaze direction had been found to have an effect on frontal EEG asymmetry (Hietanen et al., 2008; Pönkänen et al., 2011). They suggested that personal qualities of the stimuli could have contributed to the results, because the identities of the stimuli were different in the three experiments. Also in the most recent study by Pönkänen and Hietanen (2012) the stimuli did not interact with the participants before the experiment, whereas in the earlier studies (Hietanen et al., 2008; Pönkänen et al., 2011) the stimuli interacted with the participants beforehand e.g. during preparations for physiological recordings. Pönkänen and Hietanen (2012) suggest that this prior interaction may have had an effect on the results. It is possible that personal qualities of the stimuli could have contributed to the results of the present study as well. In the present study, children saw the human stimulus before physiological recordings. The human stimulus helped with preparations for the physiological recordings, but aimed to interact as little as possible with the children. It is possible that the avoidance of interaction on behalf of the human stimulus model could have affected the results.

There were also some other differences in experimental design of the present study compared to the studies conducted with adults, where gaze direction did have an effect on frontal asymmetry (Hietanen et al., 2008; Pönkänen et al., 2011). In the studies with adults, faces were shown through a voltage sensitive liquid crystal shutter, which changed between opaque and transparent in 3 milliseconds whenever stimuli were shown. In the present study, faces were shown through an aperture with a black curtain that was lifted by the experimenter in approximately 1 second whenever stimuli were shown and then lowered again. The lifting and lowering of the curtain may have caught the attention of children and disturbed concentration on the stimulus and affected EEG results. Also, in the study by Hietanen et al. (2008) and Pönkänen et al. (2011), a short audio signal was presented through speakers 5 seconds before the start of the next trial to direct the participant's attention to the shutter. No such signal was given to child participants in the present experiment, and the moment the stimulus was exposed came as a surprise. Thus, children may not have been as oriented to the faces at time of exposure compared to the adult.

Furthermore, in the studies of adults, trials lasted for 5 seconds (Hietanen et al., 2008; Pönkänen et al., 2011). In the present experiment only 4 seconds per trial were analysed, because of the time used to lift the curtain. The stimulus presentation time may have affected the results. The effect of stimulus duration has been studied in relation to affective-motivational responses of autonomic arousal (Helminen et al., 2011) and heart rate (Akechi et al., 2013). In the study by Helminen et al. (2011), participants were shown live human faces with direct and averted gaze for 2 and 5 seconds and then for a self-chosen period of time. Even two seconds was enough time evoke higher skin conductance responses to direct gaze compared to averted or closed eyes condition. In the study by Akechi et al. (2013), participants were shown facial stimuli for 5 seconds and for a self-chosen period of time. They found that there was more pronounced heart rate deceleration for direct gaze compared to averted gaze in participants, when stimuli was presented for 5 seconds. In the self-timing condition, gaze direction did not have an effect on heart rate. In both studies in the self-timing condition, averted gaze was looked at longer than direct gaze. In the future, the effect of stimulus presentation time on frontal EEG asymmetry should also be investigated. Also, the experimental setting could be considered unnatural. Eye contact plays an important role in social interaction and a situation where only gaze is initiated in a motionless face for an extended time period can be viewed as artificial. For example studies with infants using the still-face paradigm have showed reduced positive affect and gaze and increased negative affect, when an adult becomes unresponsive and maintains a neutral facial expression after a normal interaction episode (for a review on the still-face paradigm, Mesman, van Ijzendoorn, & Bakermans-Kranenburg, 2009).

In the study by Hietanen et al. (2008) and Pönkänen et al. (2011), the EEG signal was referenced to linked ears, whereas the central Cz was used as reference in the present study. Linked ears were not used as reference, because ear impedances were not stable throughout the experiment, for reasons such as children touching their ears. Various references have been used in research. The suitability of Cz as reference in asymmetry studies has been questioned (e.g. Allen et al., 2004). Davidson (2004) concludes that different reference electrode locations used in research on frontal EEG asymmetry is problematic, because effects are not always consistent and robust across difference electrodes. Davidson (2004) suggests that hemodynamic or metabolic measures can possibly provide an answer to this problem in the future.

On the basis of DVD recordings of the children's faces and gazing behavior, various reactions were observed during data collection. Studying of children with EEG is challenging. Some children smiled or burst into laughter when looking at stimuli. Other children appeared to be on the verge of crying in the same situation. Some children looked at the models with ease, while others discarded eye contact or shifted gaze to the direction the stimulus was looking to. Some children initiated contact by talking. Others started moving when nothing happened. Some children fiddled with the cords, which may have led to poorer impedances. The data collection took approximately 30 minutes, which may be considered a long time for a small child to sit and concentrate on looking at faces. Children were directed to attend to the faces shown, but many of the children showed difficulty following this and other directions. Six participants were excluded from the data analysis due to situational factors, which reflects the challenges faced with child-participant data gathering. Yet, these observations provide important information on the range of affect experienced by children in the situation. The recordings of gazing behavior during the experiment provided some information of where the children looked at, but cannot fully verify the exact fixation point or the exact time children looked at the target. An eye-tracking device could have provided more precise information.

It is possible that situational factors could have contributed to the results more than in studies with adults (Hietanen et al., 2008; Pönkänen et al., 2011). Some of the children participating in the experiment showed signs of anxiousness already at arrival. Some found that e.g. putting on a tightly fitted electro-cap and/or abrading skin gently in order to improve impedances was unpleasant. Separation from parent for the time of data gathering may have created anxiety in the children. In addition, except for spotlights directed at stimuli, all other lights were shut down. This may have frightened some of the more sensitive children. Dim lighting could have also caused drowsiness. Experiments were executed between 8 a.m. and 20 p.m., and thus time of day of data gathering could have created variation in results. For instance, the time of day and time of year have been found to have an effect on frontal asymmetry (Harmon-Jones et al., 2010).

Another issue concerning the study of EEG asymmetry, especially in children, is that of alpha band. In a review on alpha, Bazanova and Vernon (2014) note that no definitive division of EEG frequency range has been found and several fixed band widths have been used in research. The alpha peak changes with age, and there are many other factors that contribute to the applicable alpha range as well. Several alpha bands were explored in this experiment to ensure capturing asymmetric frontal EEG activity in children in the examined age groups. Future research may possibly specify the most suitable alpha frequency bands for different age groups or utilize individual alpha band widths.

In the future, a similar study with a larger number of participants would be preferable for more reliable analysis methods and results. Comparing different child age groups is problematic, because differences between groups can be due to not only age and developmental issues, but also individual differences among participants within groups. One possibility is that trait asymmetry differences and situation-dependent interindividual variability differences in reading of social stimuli may conceal the effects on gaze direction and stimulus type (Uusberg et al., 2014). For example, autistic traits in typically developing individuals have been associated with altered brain activity in the neural circuit for social attention perception while viewing others' eye gaze (Nummenmaa, Engell, von dem Hagen, Henson, & Calder, 2012). Personality has been found to influence processing of eye gaze direction and emotional facial expression during a target detection task (Ponari, Trojano, Grossi, & Conson, 2013). In the study of resting state, Hagemann, Naumann, Thayer, and Bartussek (2002) found that about 60% of the variance of the asymmetry measure was due to individual differences in trait, and 40% of the variance was due to occasion-specific fluctuations in most scalp areas.

This research extends our knowledge of the influence of perceived gaze direction on affective-motivational neural responses from adults to 5- and 7-year-old children. In conclusion, the present study did not provide evidence of the perceived gaze direction of animate and inanimate models having an effect on frontal EEG asymmetry in 5- and 7-year-olds. The results of this study indicated that perceived gaze direction (direct versus averted) of an animate in comparison to an inanimate model may have different effects on frontal EEG activity in children, dependent of the frontal channels and alpha bands analysed. Yet, with a small sample size, caution must be applied. Observed differences in frontal EEG activity were not significant and further conclusions cannot not be made. Several factors may have caused the results of this study. Studies suggest that the mental and neural processing of gaze direction develops with age. The development of these processes may be at a stage where gaze direction does not yet activate the affective-motivational neural systems efficiently. It is unclear to what extent methodological issues may have contributed to the results of this study. In the future, more studies concerning children in this area of research are required. Longitudinal research should be executed in the future to provide more information on the influence of perceived gaze direction to frontal EEG asymmetry during development, taking contributing individual factors into account.

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APPENDICES

Appendix 1: Animismikysely

TAMPEREEN YLIOPISTO Päiväys__________

ANIMISMIKYSELY

Lapsen nimi ____

Syntymäaika ____________

Sukupuoli ____________

Ärsykkeiden järjestys: 1. _____________ 2. _____________

1. Näkikö xxx sinut kun verhot olivat auki?

Kyllä ____ leikisti/oikeasti? Kyllä _____ leikisti/oikeasti?

Ei ____ Ei _____

Vastaa seuraaviin kysymyksiin siten tapahtuiko tai voisiko jotain tapahtua ”oikeasti”, ei ”leikisti”.

2. Katsoiko xxx sinua silmiin?

Kyllä ____ Kyllä _____

Ei ____ Ei _____

3.Harmittaisiko xxx:a, jos se joutuisi olemaan pitkään yksin?

Kyllä _____ Kyllä _____

Ei _____ Ei _____

4.Kuulisiko xxx, jos puhuisit sille?

Kyllä _____ Kyllä _____

Ei _____ Ei _____

TAMPEREEN YLIOPISTO Päiväys__________

5.Voisiko xxx vastata, jos kysyisit siltä jotain?

Sanoilla vai esim. nyökkäämällä / pudistamalla päätä?

Kyllä	_____	Kyllä	_____
Ei	_____	Ei	_____

6.Voiko xxx haluta jotain, esim. kirjan tai lelun?

Kyllä	_____	Kyllä	_____
Ei	_____	Ei	_____

7.Jos tapahtuisi jotain mukavaa, tulisiko xxx iloiseksi?

Kyllä	_____	Kyllä	_____
Ei	_____	Ei	_____

8.Tietääkö xxx minkä värinen paita sinulla on?

Kyllä	_____	Kyllä	_____
Ei	_____	Ei	_____

9.Voiko xxx:lla olla kavereita?

Kyllä	_____	Kyllä	_____
Ei	_____	Ei	_____

10.Onko xxx elävä?

Kyllä	_____	Kyllä	_____
Ei	_____	Ei	_____

Mistä sen tietää?

____

____

____

Note. XXX was replaced with the name of the human model and the name of the dummy model when questioning.

Appendix 2: Distribution of the animism questionnaire yes-answers

Distribution of the animism questionnaire yes-answers

Question	Age group	Yes-answers			
		human		dummy	
		n	%	n	%
1 Did X see you when the curtains were up?	5-year-olds	16	100	14	88
	7-year-olds	18	100	12	67
2 Did X look you in the eyes?	5-year-olds	16	100	14	88
	7-year-olds	15	83	14	78
3 Would X be sad, if she were to be alone for a long time?	5-year-olds	13	81	11	69
	7-year-olds	16	100	12	67
4 Would X hear you, if you spoke to her?	5-year-olds	15	94	11	69
	7-year-olds	17	94	3	17
5 Could X answer, if you asked her something?	5-year-olds	14	88	4	25
	7-year-olds	17	94	3	17
6 Could X want something, e.g. a book or a toy?	5-year-olds	14	88	9	56
	7-year-olds	15	88	7	41
7 If something nice were to happen, would X become happy?	5-year-olds	16	100	12	75
	7-year-olds	18	100	11	65
8 Does X know what color shirt you have on?	5-year-olds	14	88	9	56
	7-year-olds	17	94	5	28
9 Could X have friends?	5-year-olds	14	88	11	69
	7-year-olds	18	100	14	78
10 Is X alive?	5-year-olds	14	88	2	13
	7-year-olds	18	100	2	11

Note. The Animism questionnaire questions were translated for this table. Questions were presented in Finnish to children (Appendix 1).
Note. X was replaced with the name of the human model and the name of the dummy model when questioning.
Note. Percentages (%) presented are *valid* percentages due to missing answers.